DCA13MA120

Human Performance Factual Report

Addendum 1

Attachment 1

“Human-Centered Automation” slideshow seen during CRM Initial training by the FO in 2008

(76 pages)


HCAT
HUMAN
CENTERED
AUTOMATION
TRAINING

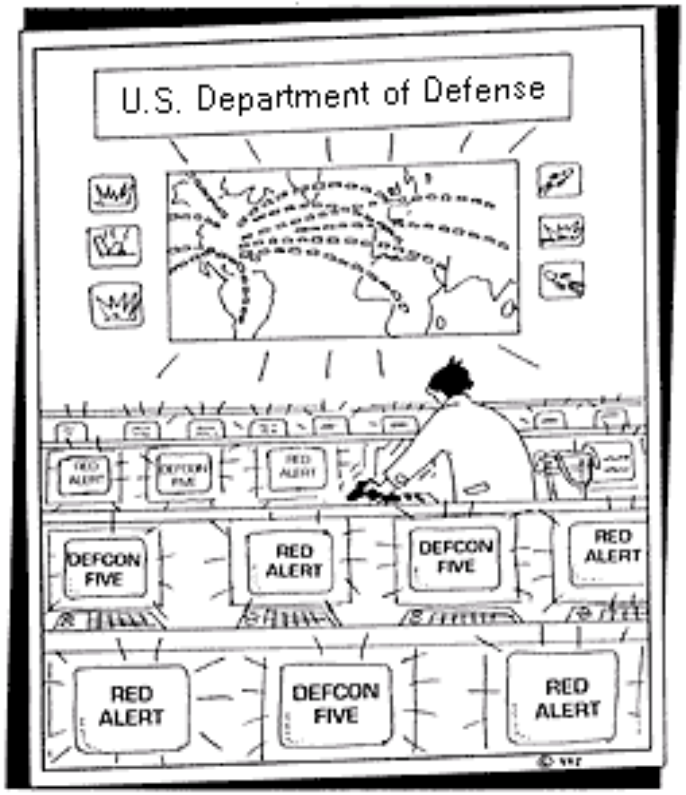
The Agenda

- **Nature of Automation**
- **Automation Policy**
- **Threat and Error Management**

  Threats – “What’s it doing now?”

  Strategies to effectively manage automation
- **Case study AA 965 “Cali”**

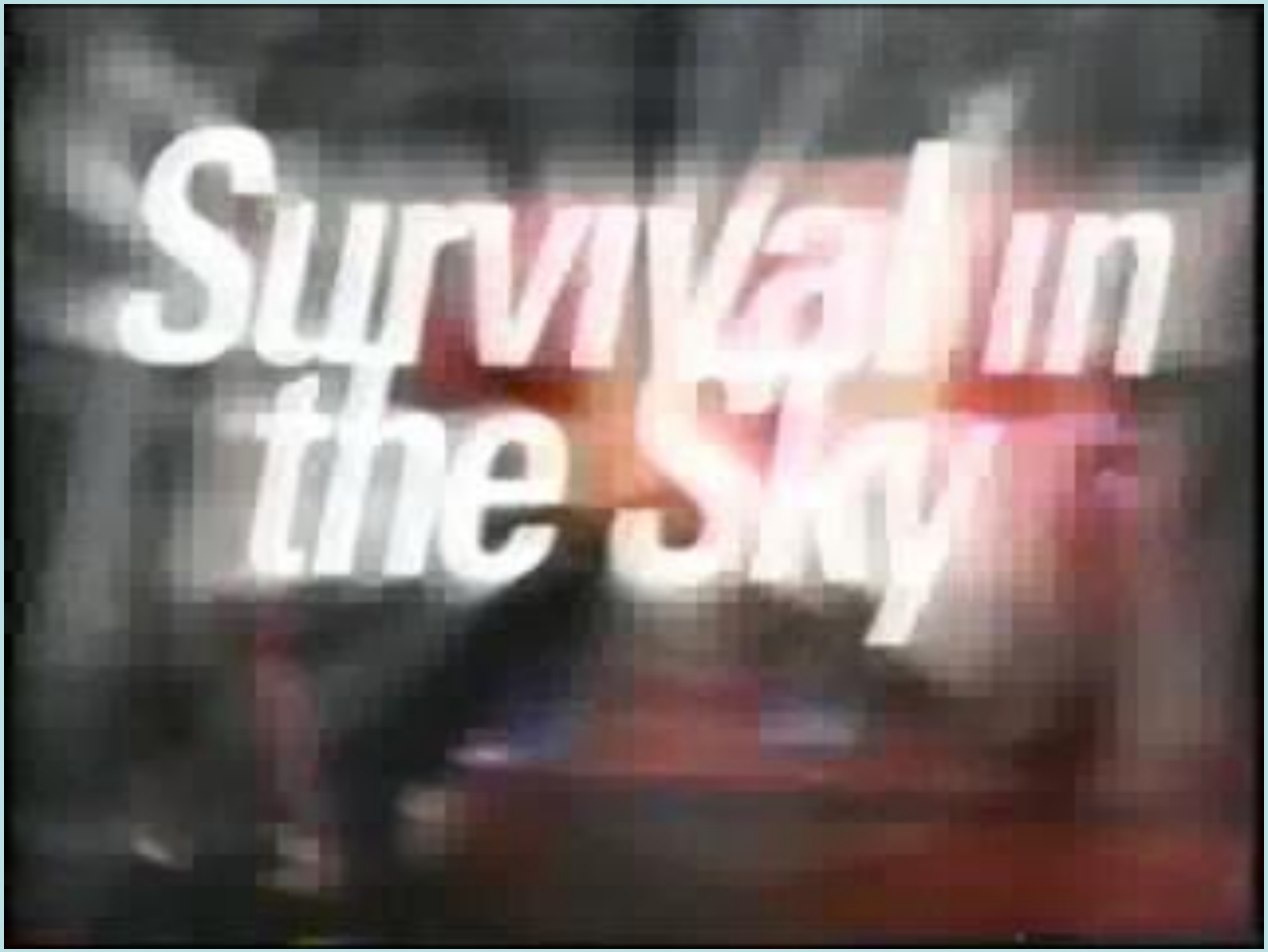
To ERR Is Human



Bernie decides to clean the computer equipment and unwittingly wages war on 14 different countries.

To **REALLY** screw up, you need a computer!

Air Inter- Survival in the Sky



Air Inter- Survival in the Sky

Nature of Automation

Intended Expectations

- Reduced workload and fatigue
- Fewer errors
- Enhanced SA
- Increased efficiency
- Enhanced safety

Nature of Automation

Reality: Reports from pilots who use it!

Workload	**Increased, Decreased, More mental**
Errors	**More, Fewer, Harder to catch**
SA	**Degraded, Enhanced**
Efficiency	**Decreased, Increased**
Safety	**Compromised, Enhanced**

Automation is a different kind of tool

To get the intended benefits

and

avoid the "bad and the ugly"

Takes a

MUTUAL COMMITMENT

What challenging environments do crews encounter operating automated aircraft?

Non - Radar / High Terrain Environment

Long Duty Periods and Fatigue

Display Differences

ETOPS / LRN International Ops

Area and Special Airport Qualifications

Automation in Flight Operations
"The Third Crewmember"

FMS

Fast/accurate computations

Contingency planning

Enhances crew SA

Creates time for:

Planning /problem solving

Decision making

Monitoring - challenging -verification

It is not meant to challenge a crewmember's role or responsibilities, but rather to…


Compliment a Crew's Strengths
Judgment
Situation assessment
Decision making ability
How are you going to know what has been entered in the Flight Management System (FMS)?

Control Display Unit (CDU)

Two Questions in Mind Prior to Executing Any Change:

1. What do I expect the airplane to do now?

2. How do I verify it?

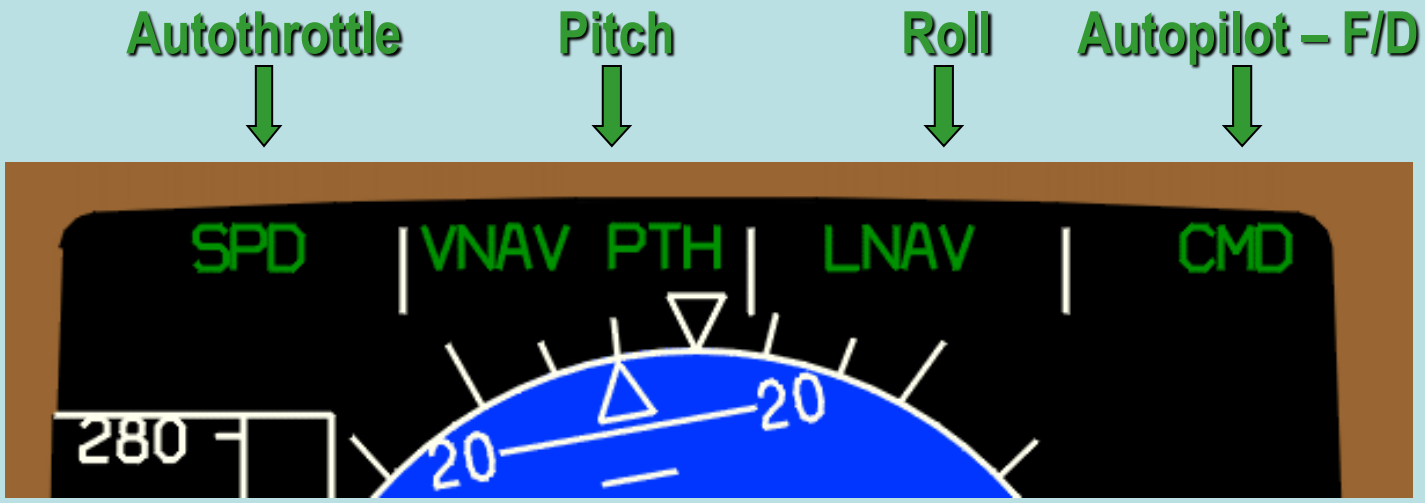
Obtain **confirmation** before **EXEC**uting any change

Verbalize
Verify
Monitor

Long term changes

Flight Mode Annunciator (FMA)

Mode Awareness Strategies



Anticipating Automatic Mode Changes

- VNAV PTH to VNAV SPD when energy state is high
- VNAV PTH to ALT HOLD during nonprecision approach or STAR

EFIS - Map Display

Automation Policy

LOSA

Data shows that…

“Crews that verbalized made fewer errors.”

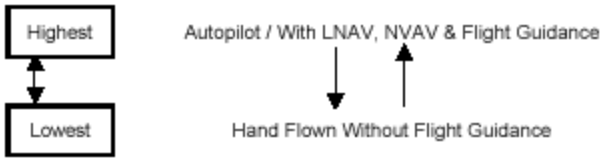
Automation Policy

General Automation Policy

Pilots shall be proficient in all capabilities of their aircraft including the automated systems. Continental Airlines/Continental Micronesia policy is to fly the aircraft using the highest level of automation, *consistent with the requirement to maintain basic flying skills.*

Pilots should realize the more complex the situation, the higher the threat level. As threats increase, automation usage when properly applied, will improve overall performance and safety. Pilots are authorized to choose an appropriate level of automation consistent with a changing flight environment.

Levels of Automation



There are many variations between the highest and lowest levels of automation. Select the level that optimizes situational awareness while reducing pilot workload. Hand flying to maintain proficiency should only be accomplished in low threat environments.

- With any mode changes to the MCP, the PF should **verbalize** the change(s). Both pilots should **verify** the change(s) using the FMA and **monitor** for expected aircraft performance.
- When selecting the Autopilot and/or Auto throttle on or off, the PF should verbalize the change. Both pilots should verify the change and monitor for expected aircraft performance.

Threat And Error Management

General

Threat & Error Management (TEM) is an essential part of our improved level of performance that will enable them to deal with the increased challenges of maintaining a safe operation. A threat is anything that increases the complexity of the operation and, if not managed properly, can decrease safety margins. To effectively manage threats, they must be identified, then assessed, and countered. Identification of threats comes

Verbalization between crewmembers is extremely important for flight deck situational awareness. Many threats and errors can be countered by effective communication. Pilots shall **"verbalize, verify and monitor"** in the following manner:

should **verbalize** the change(s). Both pilots should **verify** the change(s) and **monitor** for expected aircraft performance.

“Verbalize, Verify & Monitor”

- The background on the use of this term is from LOSA 1996 and LOSA 2000, where it was documented that crews who verbalized made fewer errors.
- When one pilot verbalizes, the other pilot looks to verify that what is being stated is, in fact, what is taking place and is correct.
- Both pilots must then monitor the aircraft for expected performance.

The following safety reports are good examples of the need for an effective Automation Policy to include the term

“verbalize, verify and monitor.”

(VVM)

"ATC issued pilot discretion descend to cross Gland at and maintain 10,000'…at the same time the lead FA called and wanted access to the flight deck for a cabin write-up…(I) didn't ***verbally*** *state to the FO to take control of the aircraft*

…descending through FL280 I noticed that we were very high and not going to make the crossing restriction…we ended up crossing GLAND at approximately 15,000'…the aircraft was in V-Nav Speed versus Path descent

…earlier ATC modified our route to over SAT versus direct GLAND and we had failed to ***verify*** *that 10,000' was still in the FMC for crossing GLAND."*

UAS

*"ATC issued pilot discretion descend to cross XYZ at and maintain 10,000'…at the same time the lead FA called and wanted access to the flight deck for a cabin write-up…(I) didn't **verbally** state to the FO to take control of the aircraft*

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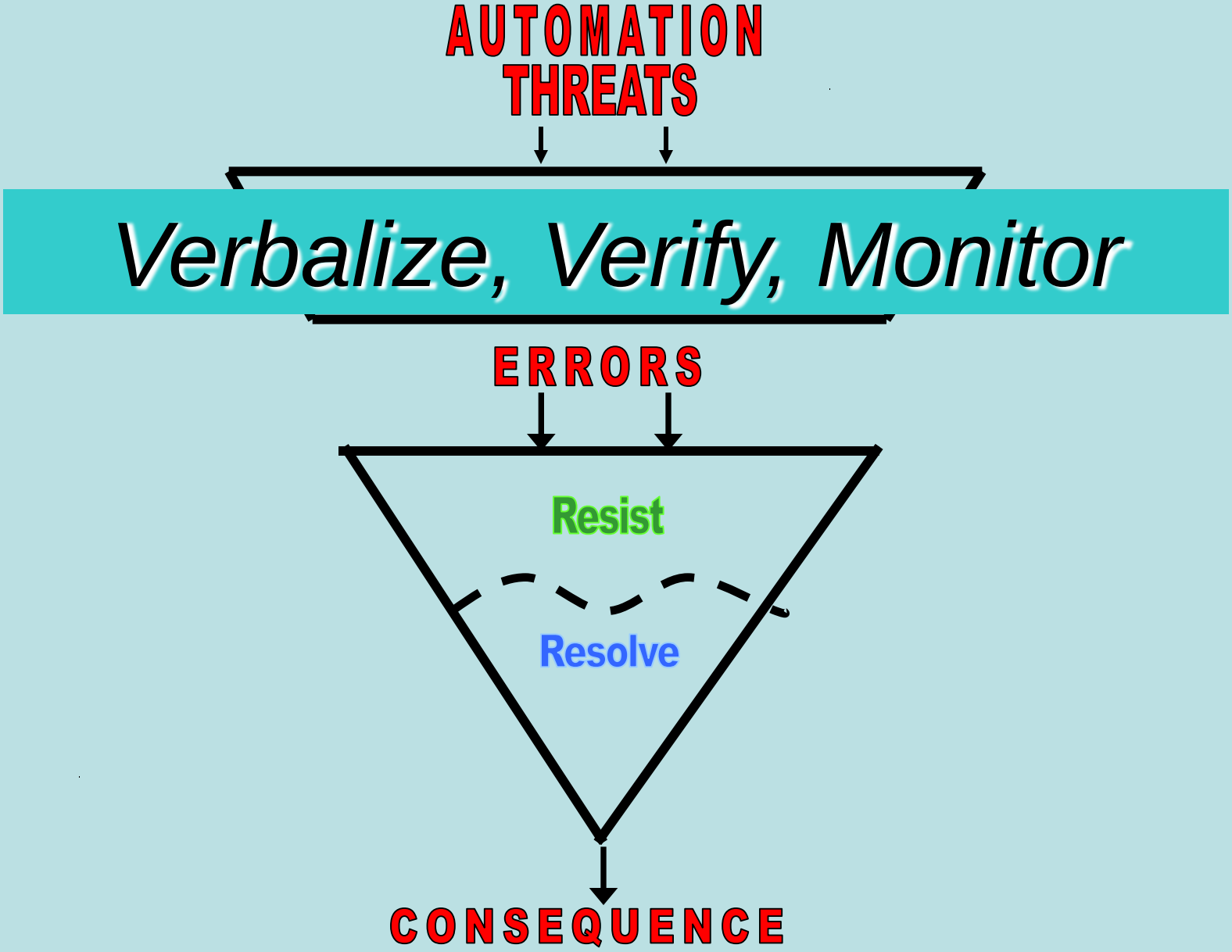
VVM is not just an Automation Strategy

"We descended below 6000 during our Dover 3 arrival. The B autopilot was in use. During the In Range Checklist, the F/O's altimeter was set at 30.34 instead of 29.34. Both pilots failed to catch the error until the approach controller called for us to stop the descent. The controller immediately re-cleared us to 5000 feet…"

Threat and Error Management



General Automation Policy

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Levels of Automation:

Autopilot/Autothrottle with LNAV, VNAV & flight guidance

Hand Flown without flight guidance

There are many variations between the highest and lowest levels of automation. Select the level that optimizes situational awareness while reducing pilot workload.

Hand flying to maintain proficiency should only be accomplished in low threat environments.

Specific Automation Policy

When the autopilot is on, the PF will normally manipulate the MCP and the CDU, and the PM will verify. When the autopilot is off, the PF will call for all changes to the MCP and the CDU. The PM will make the input and the PF will verify. The crew should brief and clearly understand their respective duties.

Specific Automation Policy

Verbalization between crewmembers is extremely important for flight deck situational awareness. Many threats and errors can be

- **When the autopilot is on, the PF will normally manipulate the MCP and the CDU, and the PM will verify.**
- **When the autopilot is off, the PF will call for all changes to the MCP and the CDU. The PM will make the input and the PF will verify.**
- **The crew should brief and clearly understand their respective duties.**

Specific Automation Policy

(continued)

- **Prior to executing any changes in the CDU, the pilot making entries should verbalize the change(s). Both pilots should verify the**
- **With any mode changes to the MCP, the PF should verbalize the change(s). Both pilots should verify the change(s) using the FMA and**
- **When selecting the Autopilot and/or Auto throttle on or off, the PF should verbalize the change. Both pilots should verify the change and monitor for expected aircraft performance.**

Automation Confusion or Frustration ?

Go up a level?
Na, go down a level!
RNP approaches?
hand fly?

I'll give ya 42 levels of automation!

Just pull your head out of your automation !

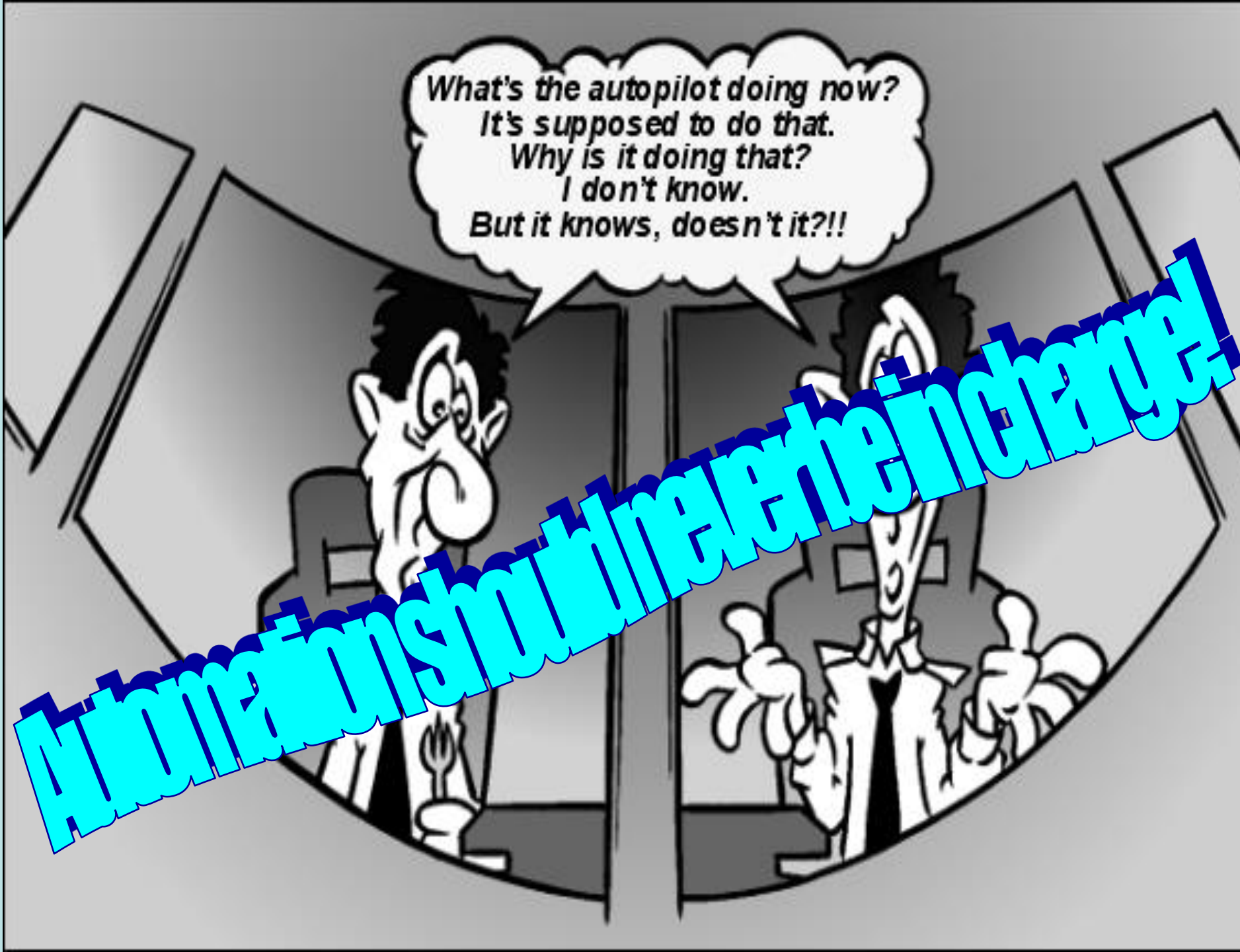
Guideline for Changing Levels

- If overloaded or confused ------ **Go Down**

- Some situations---------- **Go Up?**

“Survival In the Sky”

The Learning Channel


What's the autopilot doing now?
It's supposed to do that.
Why is it doing that?
I don't know.
But it knows, doesn't it?!!
Automation should never be changed!

Threat and Error Management

Resist

Hardware & Software that exists before the human enters

Resolve

What the human brings to the system

Critical Times

"Windows of Awareness"

What do you consider a critical phase of flight?

- **Vertical phases of flight (especially with 1000 feet of an altitude)**
- **Approaching waypoints**
- **Not established on a route of flight**
- **Below 10,000 feet**

Automation Threats

- Complacency
- Distractions
- High workload
- “Heads down” at critical times
- FMS “Dumb and dutiful”
- Mode changes
- Automation surprise
- Display differences
- Loss of basic airmanship skills

Threat  Complacency

- Assuming the automation is programmed correctly
- Over reliance on the automation
- Failure to monitor / verify
- Failure to use charts

Strategies ?

Threat Over Reliance

Flight was cleared to descend via DOVER profile ….. . CA was distracted doing the in range checklist. When he discovered the flight was going to bust the 8000 ft DOVER restriction. …. tried to correct it using automated systems rather than manually correcting the situation. CA was completing in range checklist and contacting MX with a write- up.

CA recommends better monitoring on his part and emphasizing that when bogged down by the automation, manually taking over can save the day

Strategies?

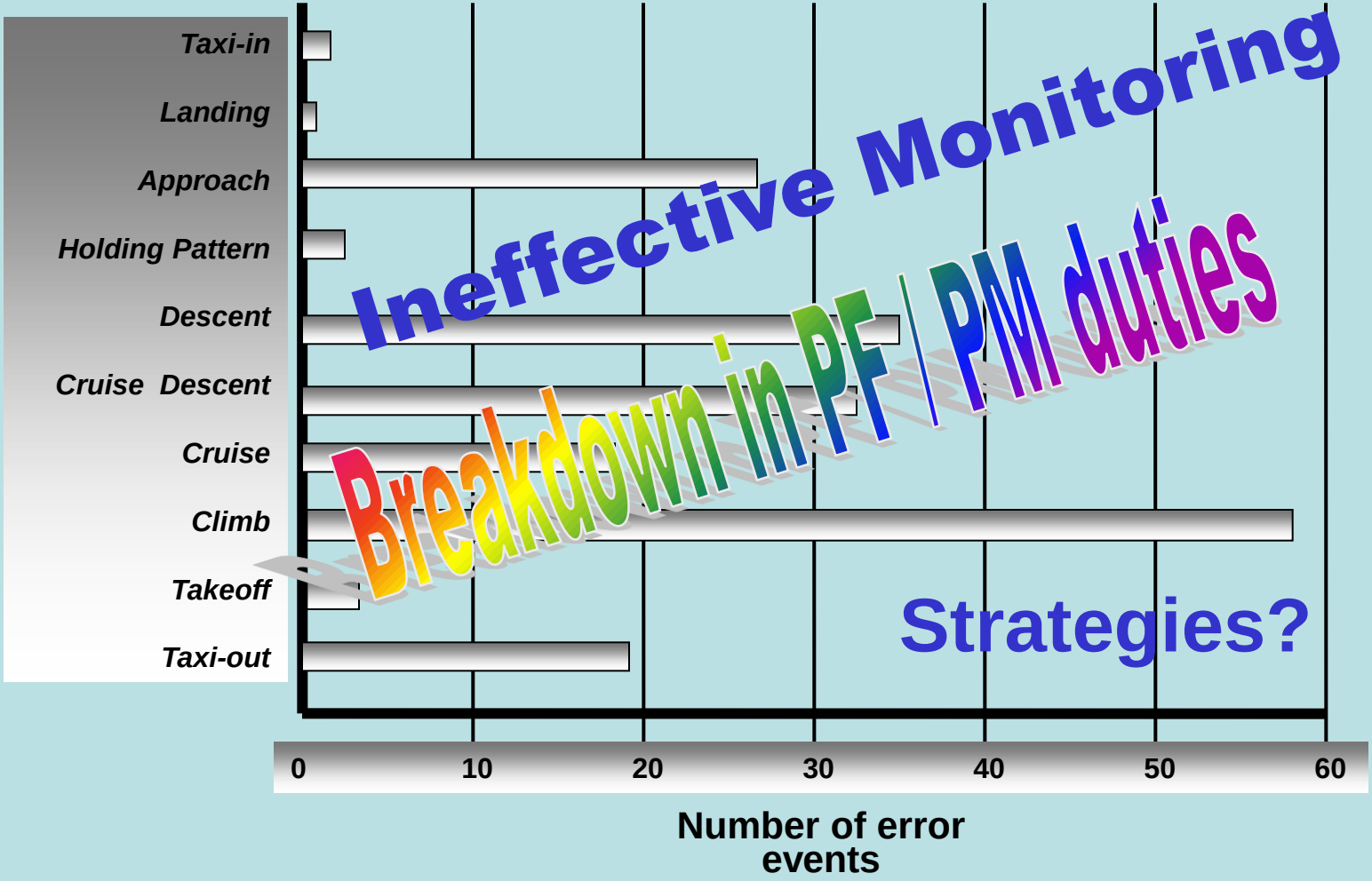
FO notes the errors as poor planning on the part of PF, late descent after VNAV did not capture descent, poor monitoring on the part of the CA.

Threat Distractions

Monitoring Errors by Phase of Flight

(Data based on 170 ASRS reports)

76% of reported monitoring errors occurred in some mode of vertical flight



Threat Distractions

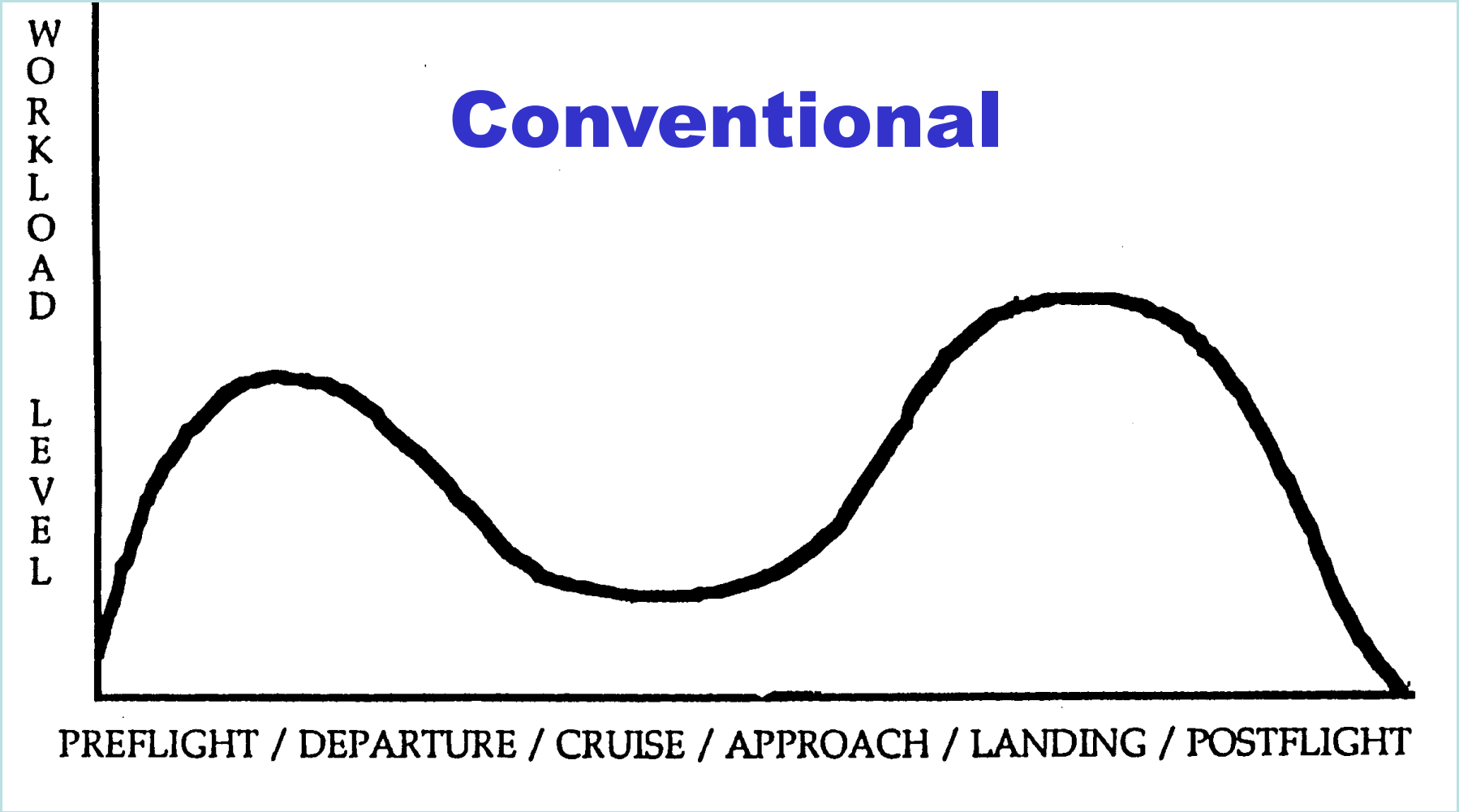
Center cleared us to descend to FL230. Selected 23000 in the Altitude Select window and pushed VNAV. At this time the FO was off the freq to contact ops. 1- 2 minutes passed while CA was organizing his charts, when BOS Center queried about the altitude. CA realized that VNAV had not properly engaged

CA notes that he errored in not properly verifying that the VNAV had engaged. He notes that in the future, more attention to detail when manipulating the auto flight system to ensure that what the acrft is doing is what the crew has intended.

Strategies?

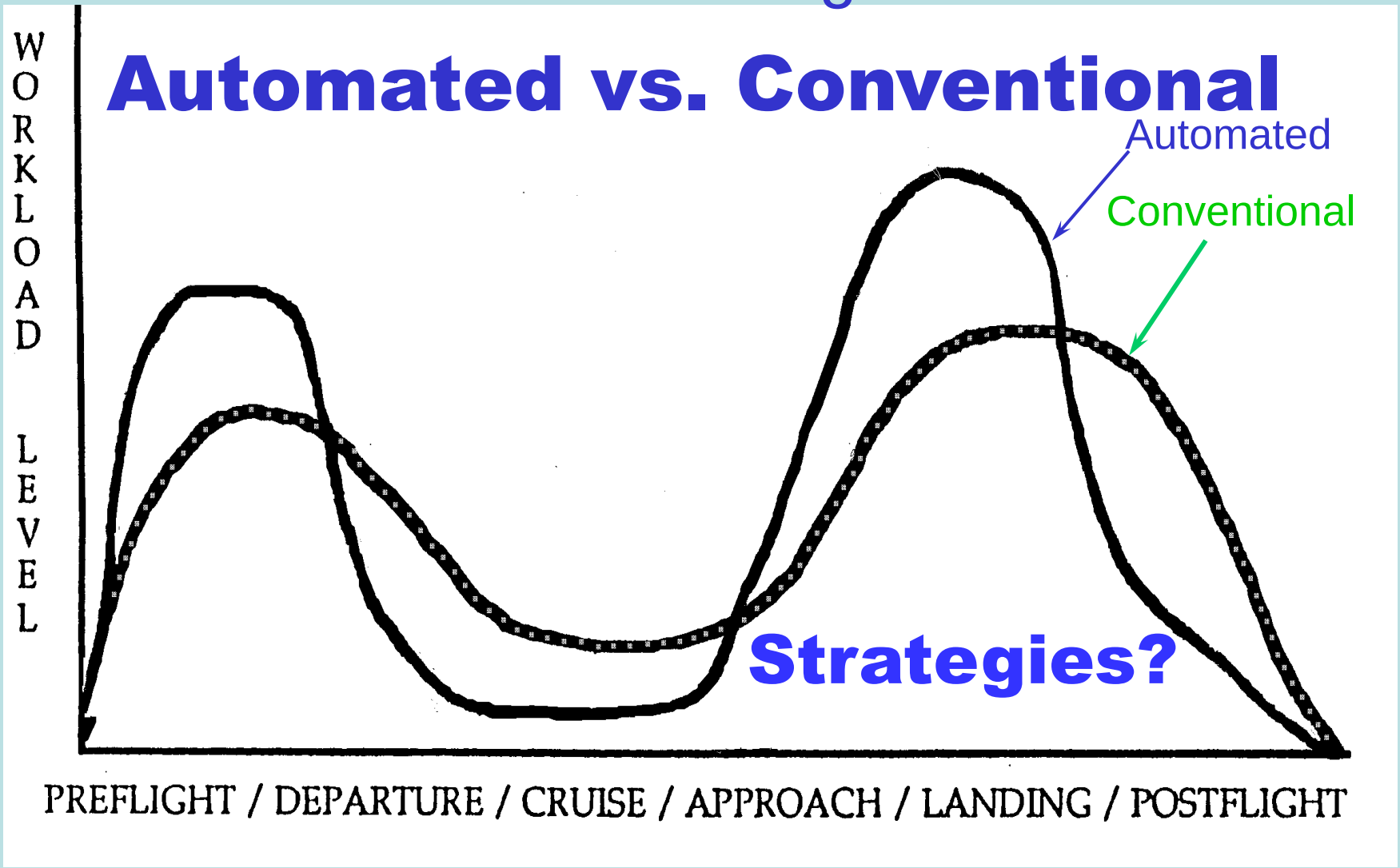
Threat High Workload

Workload Management



Threat High Workload

Workload Management



Threat Heads Down (Out of the Loop) at Critical Times

- FMC programming
- The paperwork shuffle
- Company In range and MX calls
- Getting the ATIS
- Arrival PA
- Workload Management (Late brief/checklist)

Confirm PF / PM duties

How do these influence the monitoring process?

Strategies?

Threat FMS "Dumb and Dutiful"

Accepts data as long as its in correct format

Cannot differentiate misspelled fixes

(Ex. MSY vs. MYS)

Verbalize – Verify - Monitor

Strategies?

Threat FMS "Dumb and Dutiful"

Verbalize – Verify - Monitor

….the FO did some FMS entries as the CA was deviating around the weather and maybe thought he would extend the center line to FEAST and did not get the inbound course typed in and it created a direct to FEAST

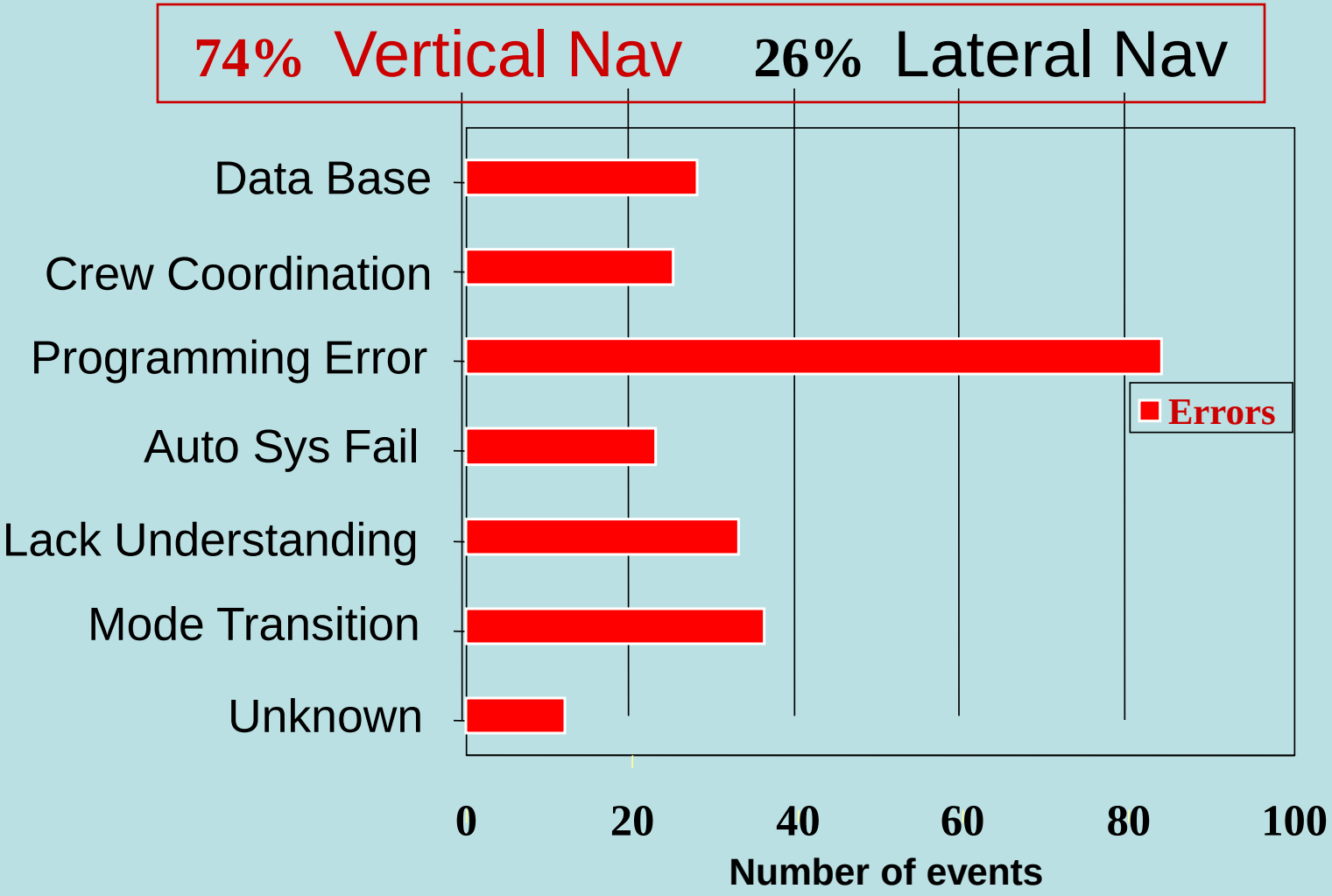
Strategies?

CA notes the errors as incorrect FMS course, not verifying before arming the LNAV

Threat Mode Changes

Mode Changing Errors

184 ASRS Reports 1990-1994



Threat  Automation Surprise

What is it doing?

What happened?

What is it going to do next?

How did we get this ------ up?

Strategies?

Verbalize - Verify - Monitor

Threat Display Differences

Strategies?

Threat

Loss of Basic Airmanship Skills

- Failure to backup automation descent planning
- Failure to use en route / arrival charts
- Loss of chart knowledge or ability to locate information

Strategies

- **Practice hand flying -** Practice in low threat environment
- Use 3 to 1 rule to back up descent
- Use the enroute charts
- Routinely brief MEA's, MSA, MOCA, etc.

Threat

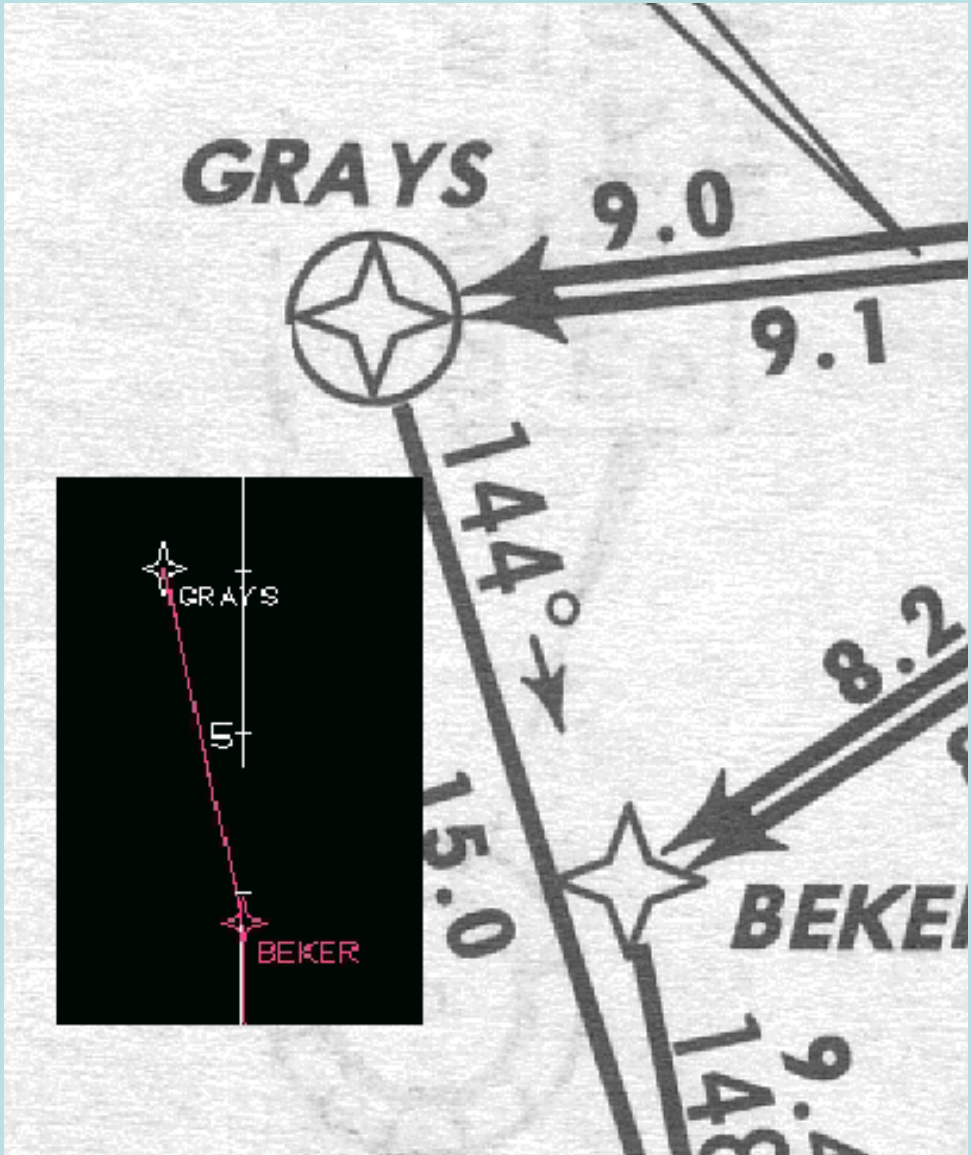
Loss of Basic Airmanship Skills

Cleared the flight to 13000 ft and flight went to 13400 ft. While climbing from 8500 ft to 13000 ft, ATC gave the flight a vector change from 250 degs to 280 degs. During the climbing turn, flight received a TCAS advisory of an acft at 10o'clock and 1200 ft below. ATC called shortly thereafter to advise the flight of traffic at 9 o'clock and 3 miles. While looking for the traffic, the acft went from 13000 ft to 13400 ft. The altitude alert went off at 13300 ft and flightcrew corrected immediately but not before climbing to 13400 ft. ATC asked the flightcrew to call. Ops Manager stated the flight had "loss of separation" with another acft due to the flight altitude of 13400 ft and 2.78 miles from another acft.

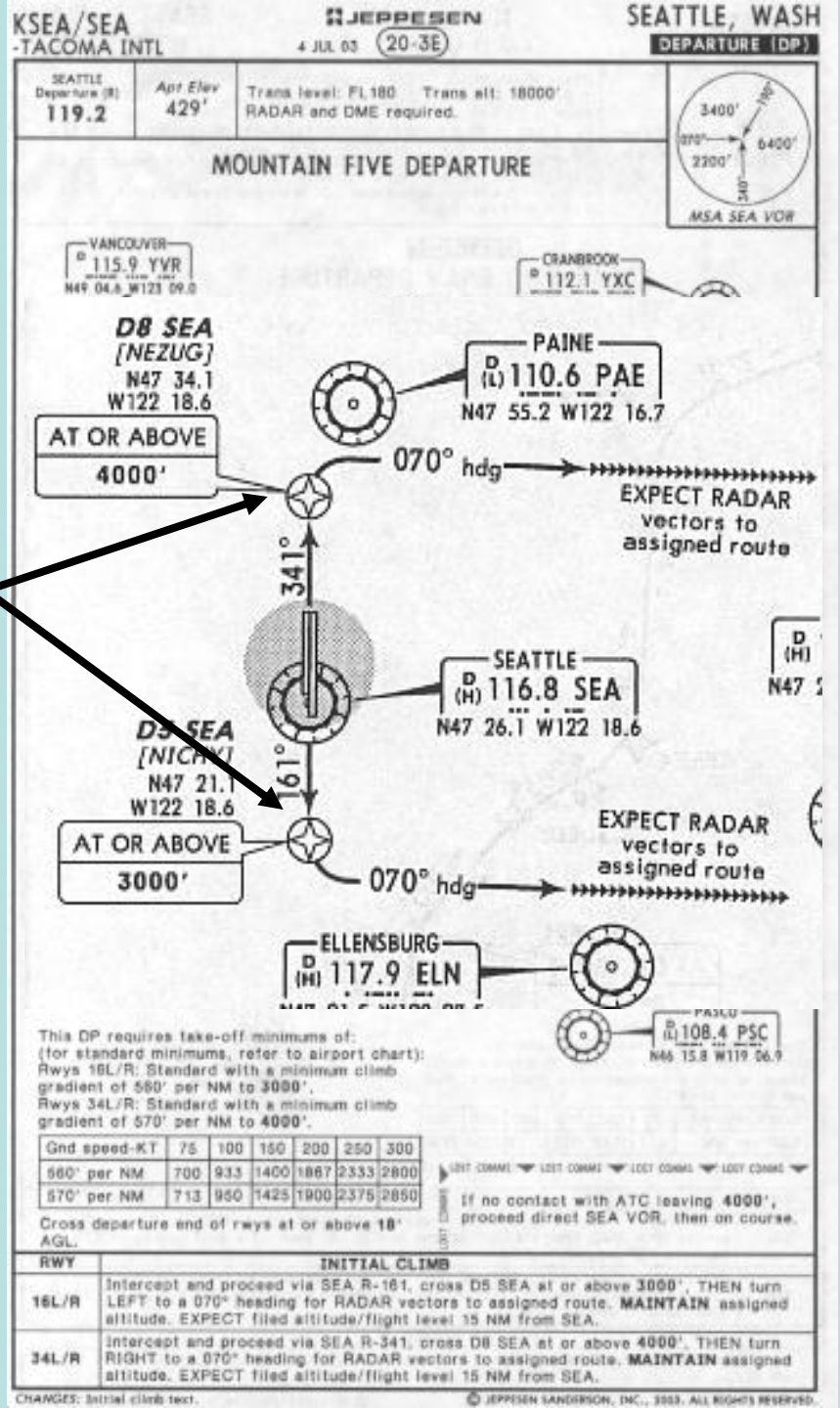
Strategies?

Ops Manager stated he filed a pilot deviation report. No autopilot was on at this time, which CA believes would have prevented this incident.

ASAP
“Hot Items”



Fly-Over Waypoints



Fly-by Waypoint –
Requires the use of turn anticipation to avoid overshoot of the next flight segment

Fly-over Waypoint –

Precludes any turn until the waypoint is overflown and is followed by an intercept maneuver of the next flight segment.

What Strategies would have prevented this event?

Fly-by versus Fly-over Waypoints

What was the Threat?

"Departing runway 34R at SEA. Flying the Mountain 5 departure. Required right turn to heading 070 at 8.0 DME (from) SEA was built into LNAV. Aircraft in LNAV turned at 7.5 DME. ATC assigned heading stating that aircraft turned "a hair to early…"

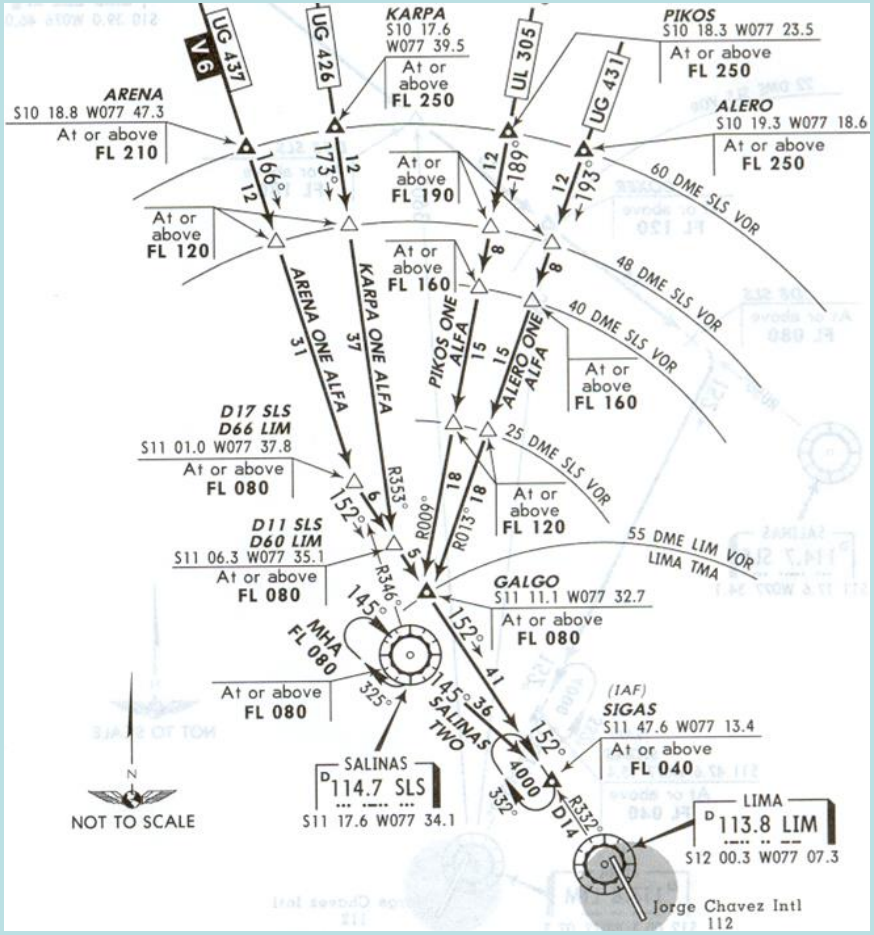
Automation Threats

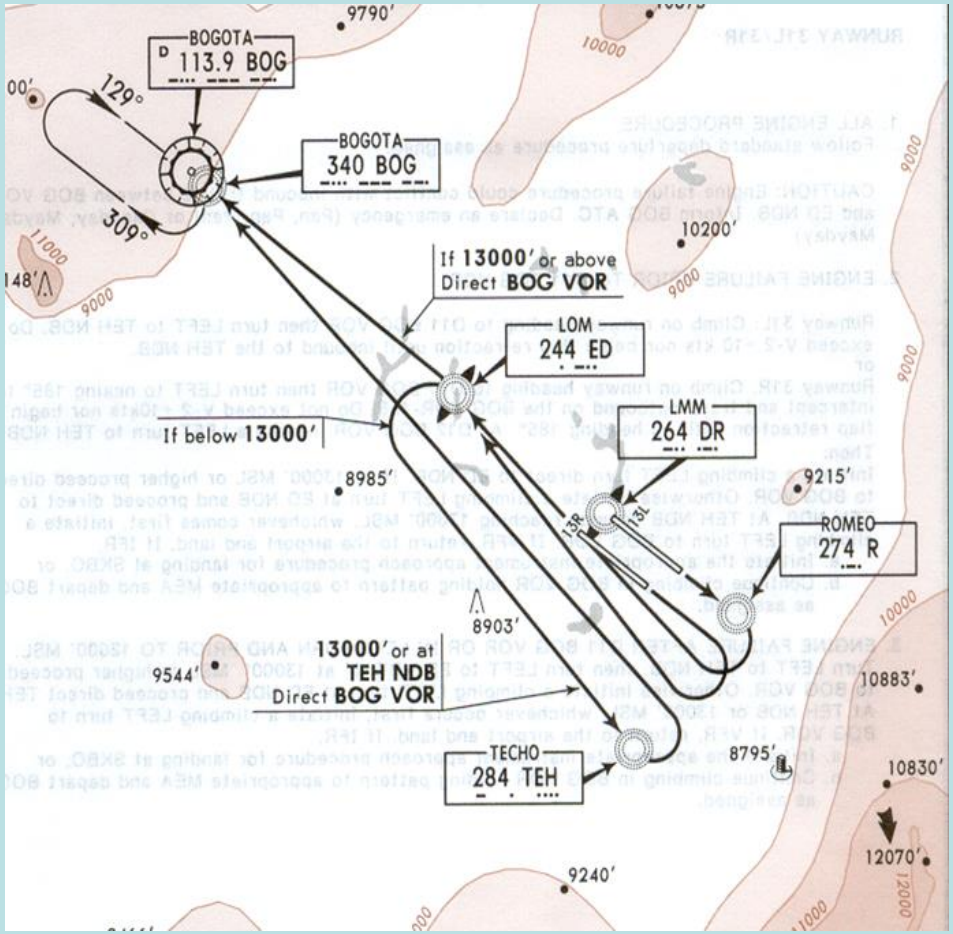
- Complacency
- Distractions
- High workload
- “Heads down” at critical times
- “Dumb and Dutiful”
- Mode changes
- Automation surprise
- Display differences
- Loss of basic airmanship skills

Any of these can lead to a “CFIT” accident

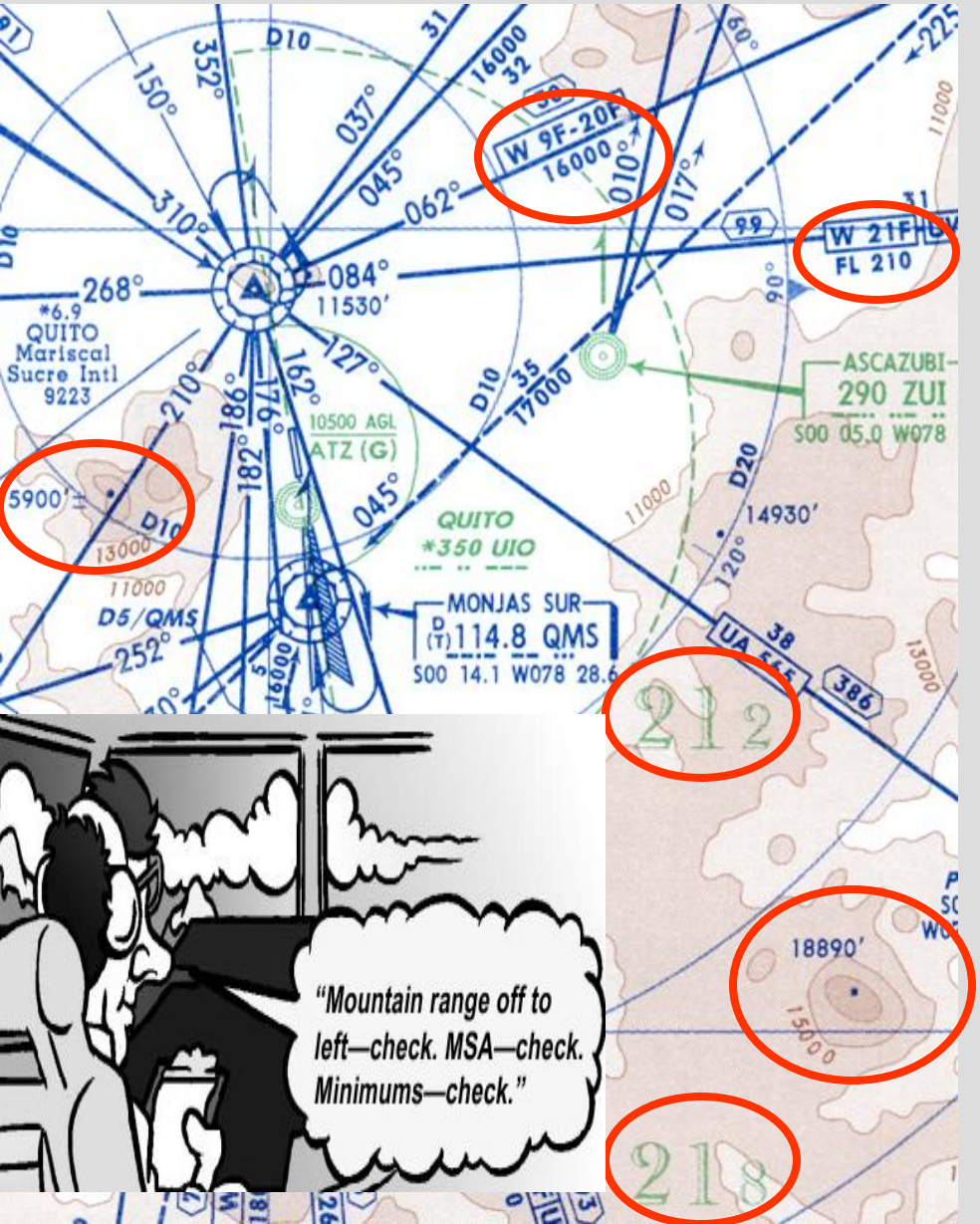
Another Threat That May Lead To CFIT

Complex instrument procedures





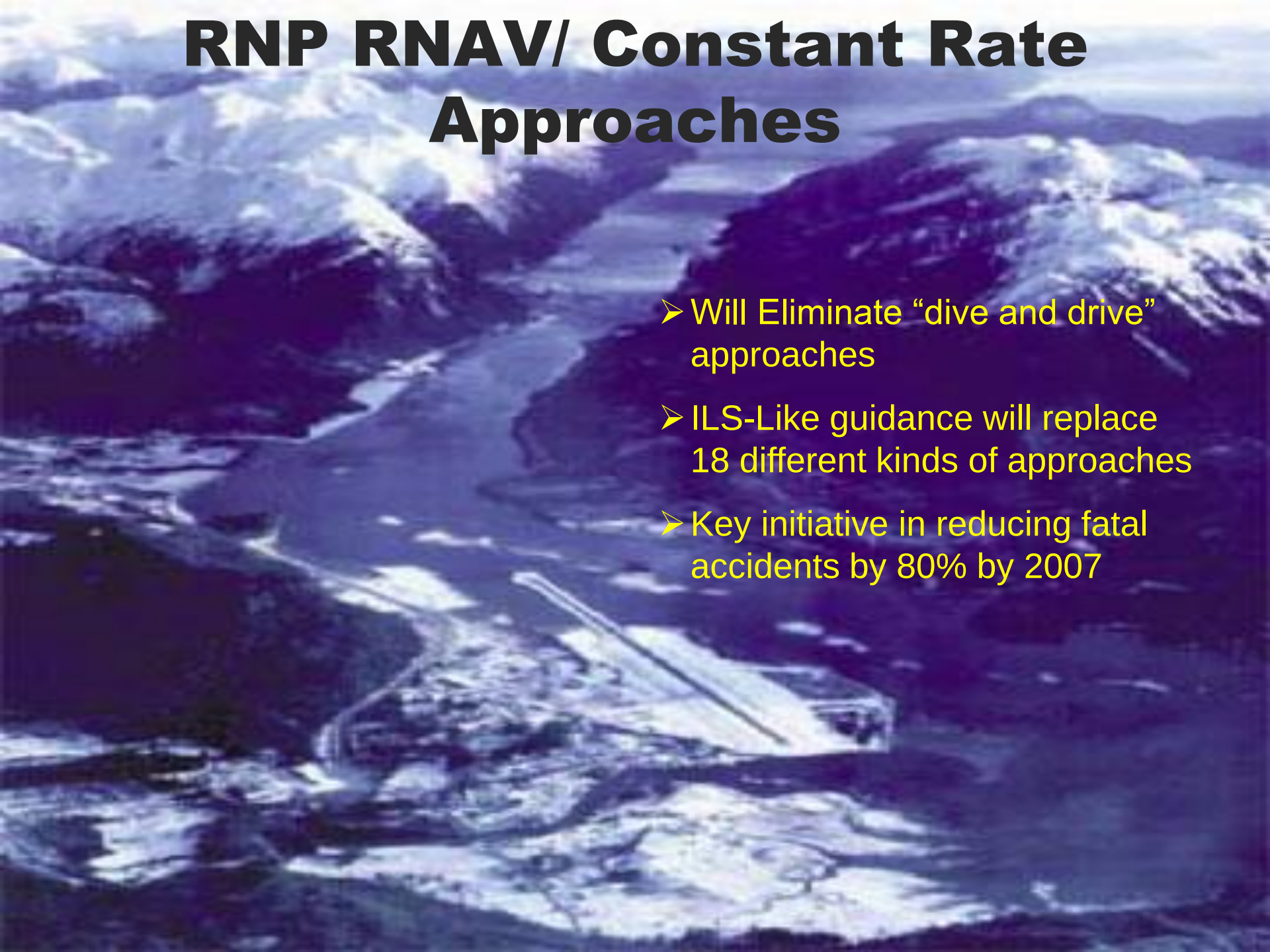
Strategies to Prevent CFIT?



Enhance Situational Awareness

- Start briefing early during low workload
- Review and use enroute/arrival charts
- Brief MSA, MEA, MOCA, etc.
- Contingency planning – “What if?”
- Proper use raw data as a backup

RNP RNAV/ Constant Rate Approaches



- Will Eliminate “dive and drive” approaches
- ILS-Like guidance will replace 18 different kinds of approaches
- Key initiative in reducing fatal accidents by 80% by 2007

RNP RNAV Approach

Strategies?

- **Practicing RNAV approaches in “good weather” low stress environment**
- **Using the QRH to setup and brief the approach**
- **Watch for the “Errors”:**

  VNAV unused / not selected during descent

  Path unexecuted

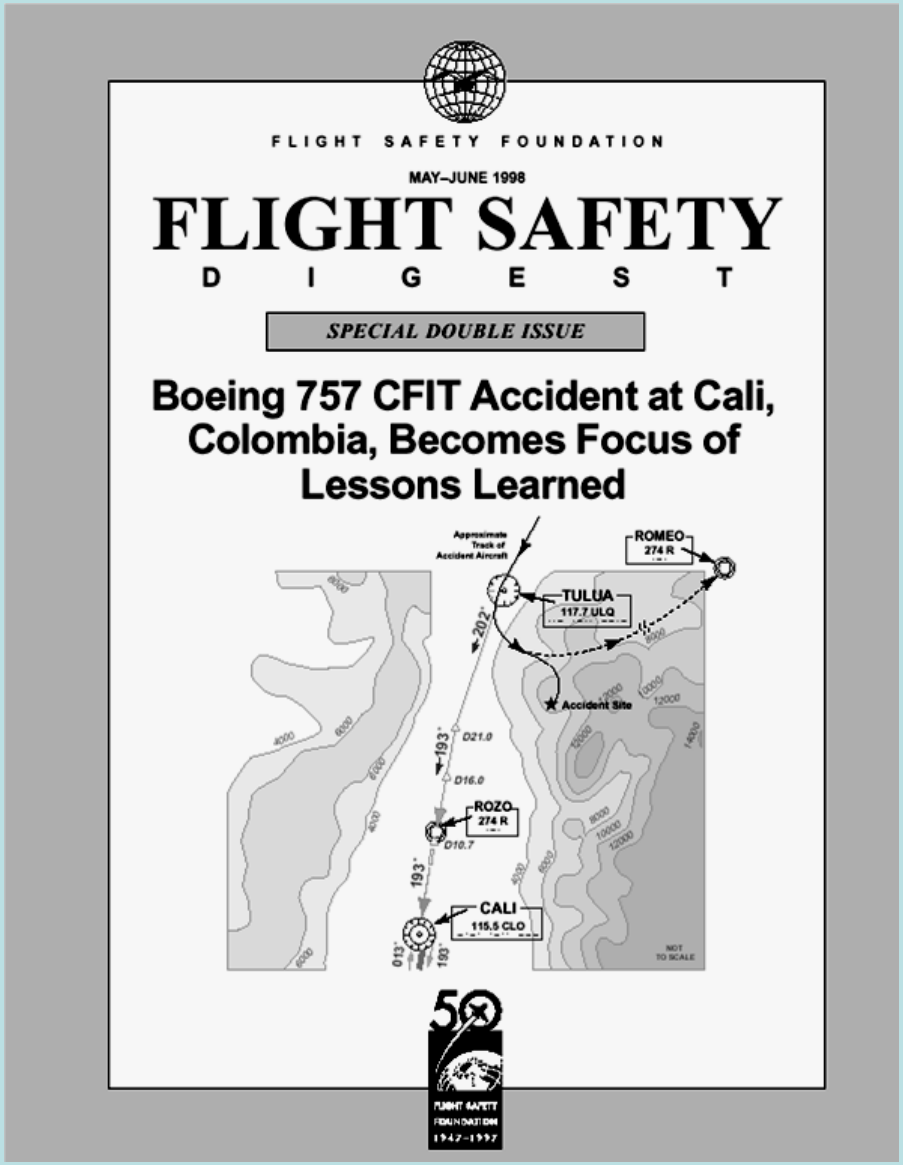
  Unable to engage VNAV at lower altitude

  Late checklist

Automation & Technology

Observable Skills to be Evaluated

- Plan and brief automation modes and configurations
- Establish guidelines for PF/PM duties for the operation of automated systems
- Plan workload and allow sufficient time for programming tasks
- Verbalize entries and changes to automated systems
- Maintain an awareness of the automation modes selected by crew or initiated by FMS
- Change level of automated system (up or down) to increase situational awareness and avoid work overload.



Cali

"An Aviator's Nightmare"

Unmanaged Threats

Unmanaged Automation error

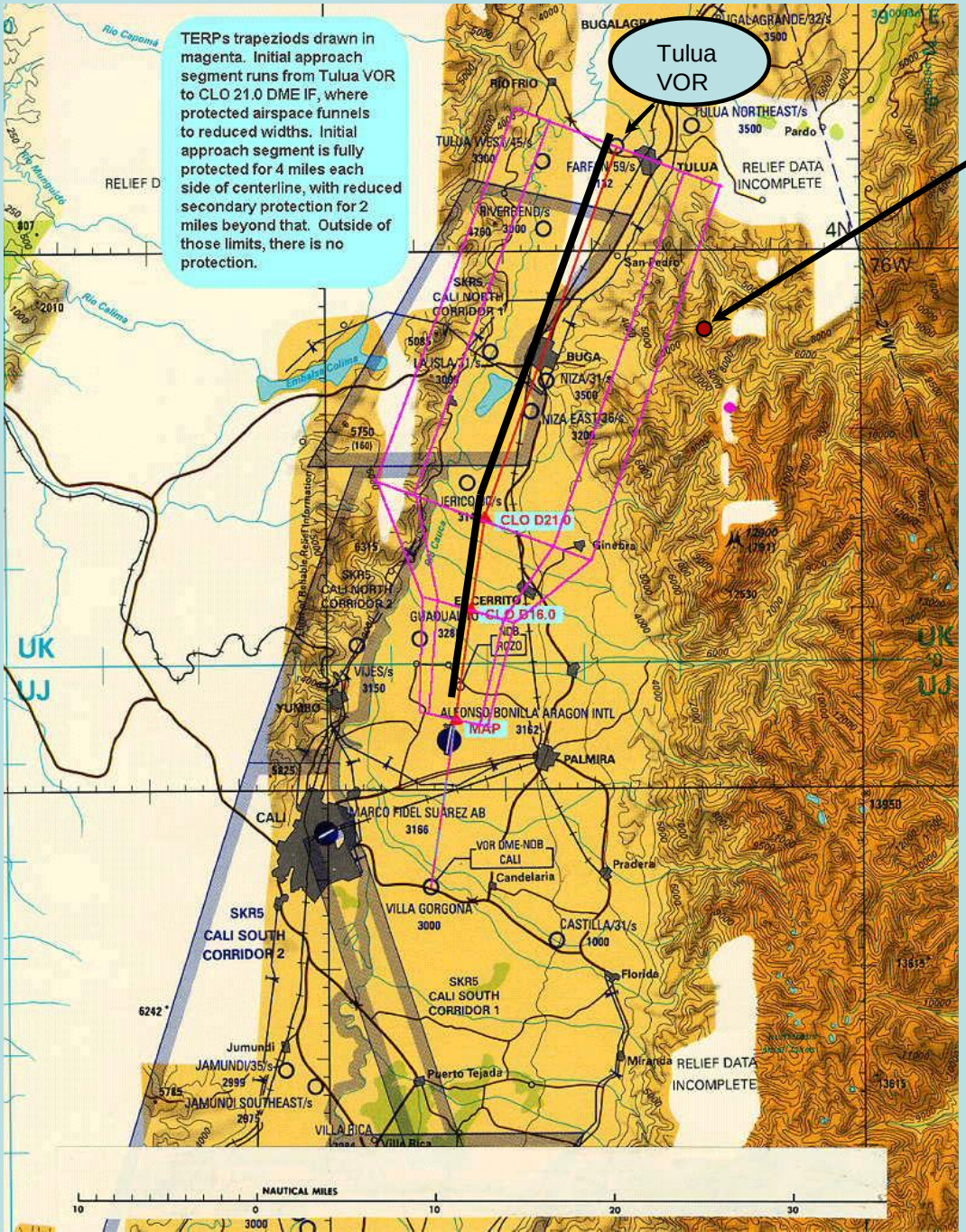
The Consequences - Tragic

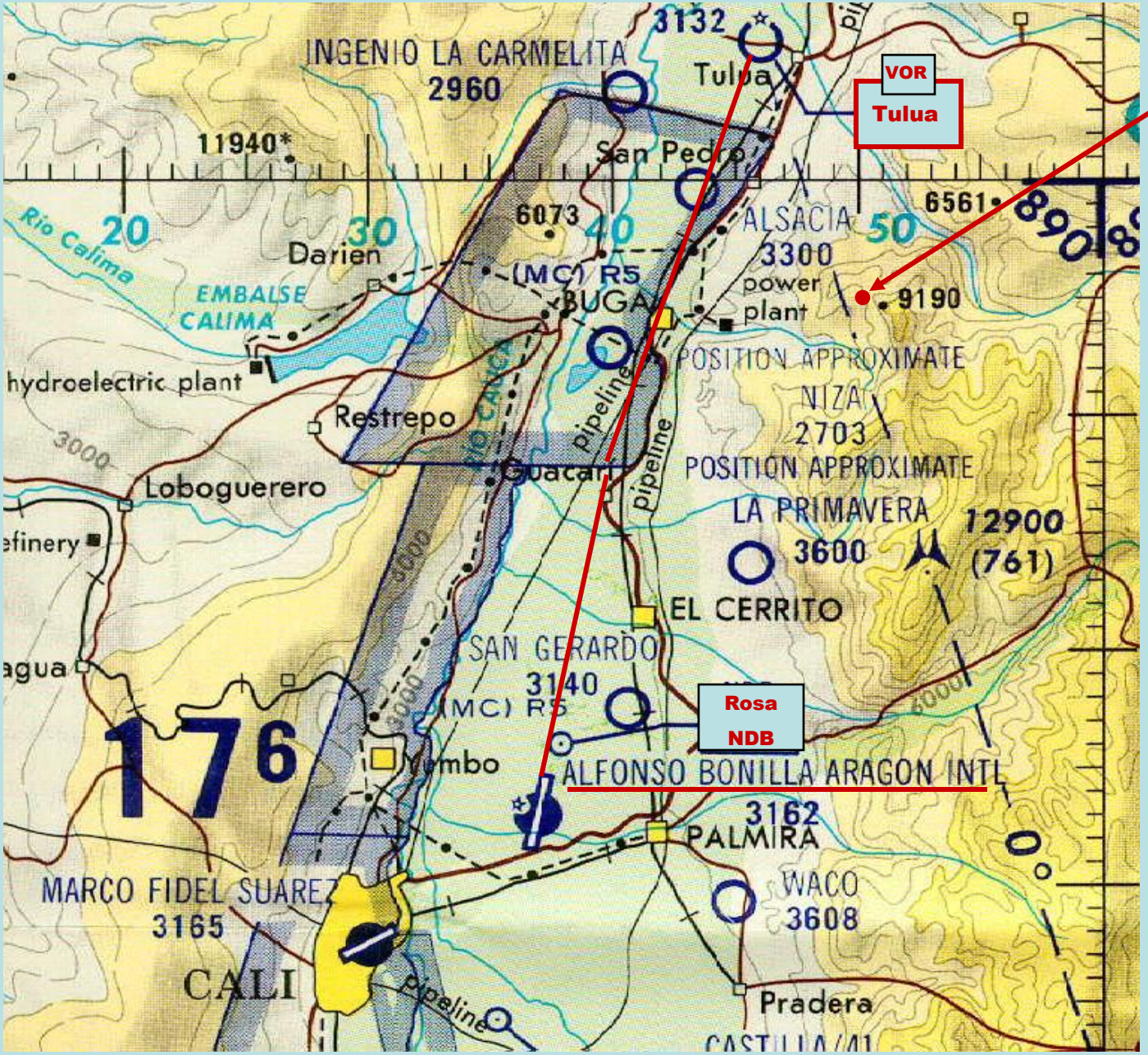
Case Study: AA 965 “Cali”

December 20, 1995

2142 local time

- Experienced, “good” B757 crew
- Capt. had been there 13 times, FO’s first
- Night with no significant weather (VMC)
- Non radar environment
- Late departure
- Long day
- FO is PF


TERPs trapeziods drawn in magenta. Initial approach segment runs from Tulua VOR to CLO 21.0 DME IF, where protected airspace funnels to reduced widths. Initial approach segment is fully protected for 4 miles each side of centerline, with reduced secondary protection for 2 miles beyond that. Outside of those limits, there is no protection.
Tulua VOR
Crash site
BUGALAGRANDE/32/s
RIO FRIO
TULUA NORTHEAST/s
TULUA WEST/45/s
FARFAN/59/s
TULUA
RELIEF DATA INCOMPLETE
RIVERBEND/s
San Pedro
SKR5 CALI NORTH CORRIDOR 1
BUGA
NIZA/31/s
NIZA EAST/36/s
JERICO/s
CLO D21.0
Ginebra
SKR5 CALI NORTH CORRIDOR 2
EL CERRITO
GUADUALITO
CLO D16.0
IDB
AO20
VIJES/s
YUMBO
ALFONSO BONILLA ARAGON INTL
MAP
PALMIRA
CALI
MARCO FIDEL SUAREZ AB
VOR DME-NDB
CALI
Candelaria
Pradera
VILLA GORGONA
CASTILLA/31/s
SKR5 CALI SOUTH CORRIDOR 2
SKR5 CALI SOUTH CORRIDOR 1
Florida
Jumundi
JAMUNDI/35/s
JAMUNDI SOUTHEAST/s
Puerto Tejada
Miranda
RELIEF DATA INCOMPLETE
VILLA RICA
NAUTICAL MILES
UK
UJ
76W
4N


INGENIO LA CARMELITA
2960
3132
Tulua
VOR
Tulua
Crash site
11940*
San Pedro
6073
6561
ALSACIA
3300
power plant
9190
Darien
(MC) R5
BUGA
Rio Calima
EMBALSE CALIMA
hydroelectric plant
POSITION APPROXIMATE
NIZA
2703
Restrepo
Guacari
pipeline
Loboguerero
POSITION APPROXIMATE
LA PRIMAVERA
3600
12900
(761)
EL CERRITO
SAN GERARDO
3140
(MC) R5
Rosa
NDB
Yumbo
ALFONSO BONILLA ARAGON INTL
3162
PALMIRA
WACO
3608
MARCO FIDEL SUAREZ
3165
CALI
Pradera
CASTILLA/41

Cali Video

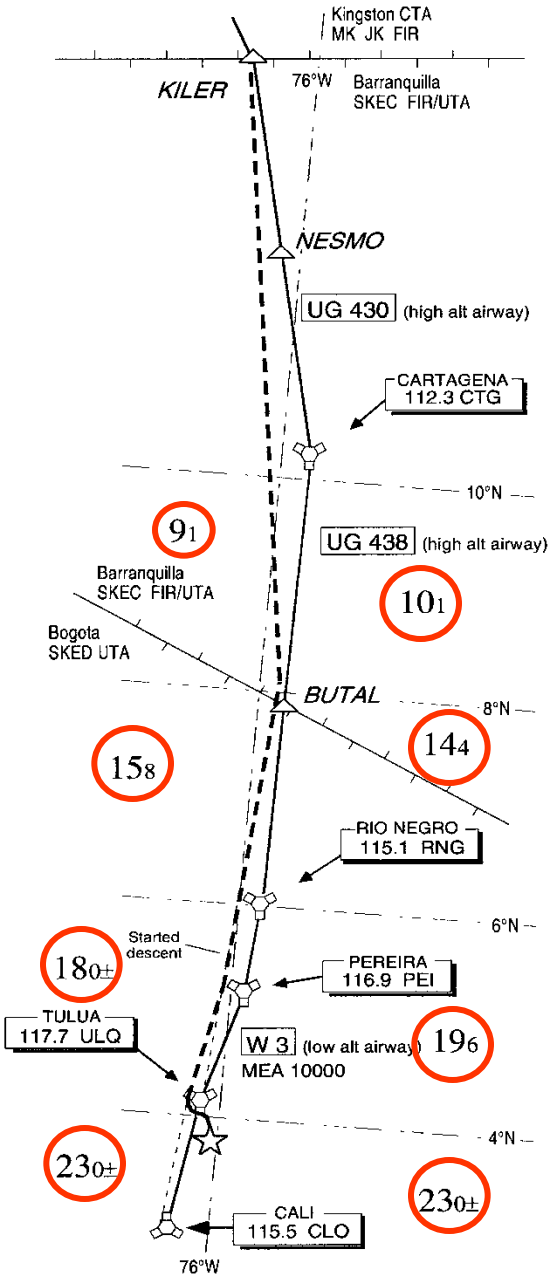
CALI COMPOSITE

by Bill Bulfer

Typical RTE and LEGS pages describing UG 430 and UG 438 from MBJ to CLO

ACT RTE 1	2/2
VIA	TO
DIRECT	MBJ
UG430	CTG
UG438	CLO

ACT RTE 1 LEGS	1/X
168°	
MJB	
166°	126 NM
BOSIK	
167°	93 NM
KILER	
166°	167 NM
NESMO	
167°	128 NM
CTG	
181°	140 NM
BUTAL	
180°	112 NM
RNG	
200°	76 NM
PEI	
210°	47 NM
ULQ	
195°	43 NM
CLO	



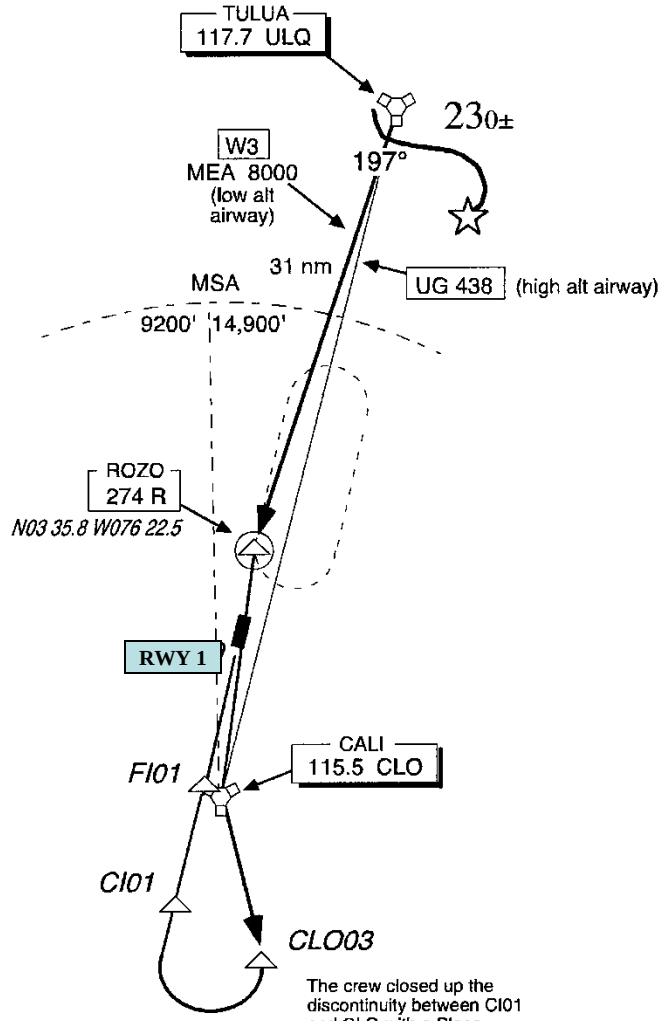
NOT TO SCALE

Selecting the ILS01 from the SKCL ARRIVALS page brought up the following:

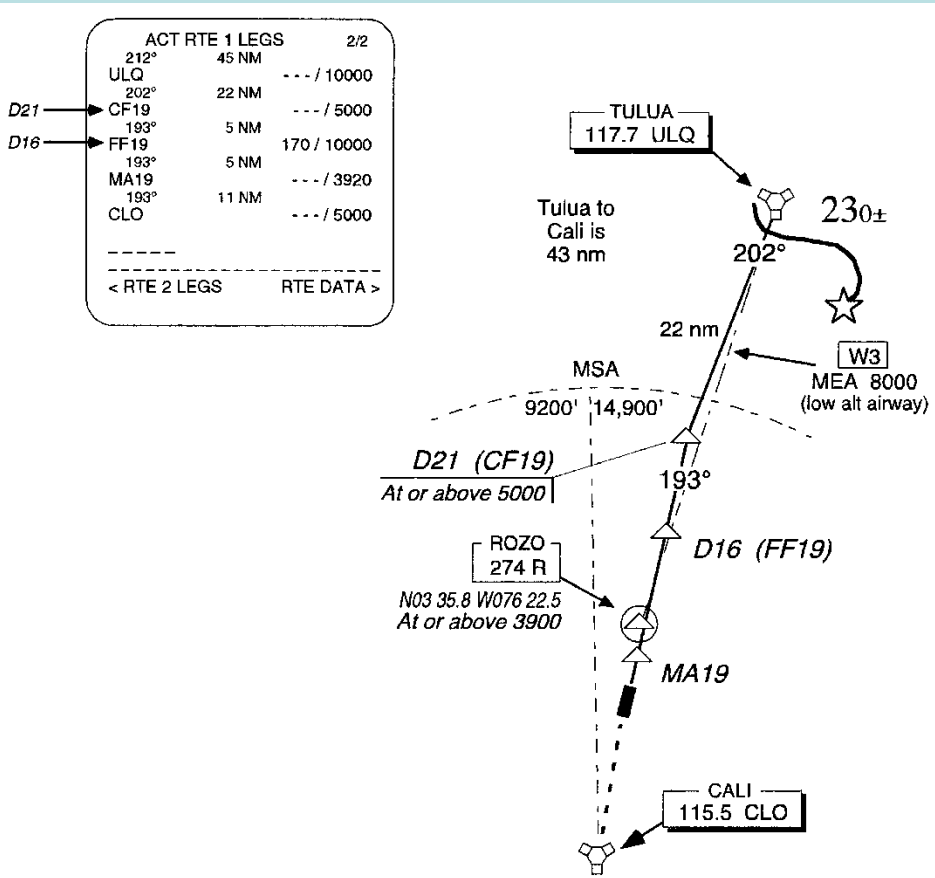
```
        ACT RTE 1 LEGS          2/2
      -- ROUTE DISCONTINUITY --
CI01
  013°          2 NM
FI01
  013°          7 NM
RW01
  013°          4 NM
ROZO
  HOLD AT
ROZO

- - - - -
-------------------------
< RTE 2 LEGS        RTE DATA >
```

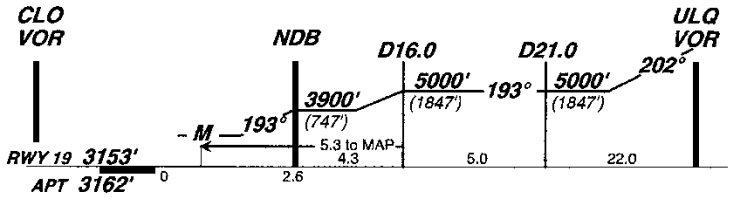
Technically, W3 should be flown from ULQ to ROZO to CLO. This has an MEA of 8000 ft to CLO with 3000 ft to lose in the course reversal.

```
        ACT RTE 1 LEGS          1/X
  210°          47 NM
ULQ
  197°          12 NM
ROZO
  190°          12 NM
CLO
  161°           3 NM
CLO03
  307°           2 NM
CI01
  013°           2 NM
FI01
  013°           7 NM
RW01
  013°           4 NM
ROZO
  HOLD AT
ROZO
```



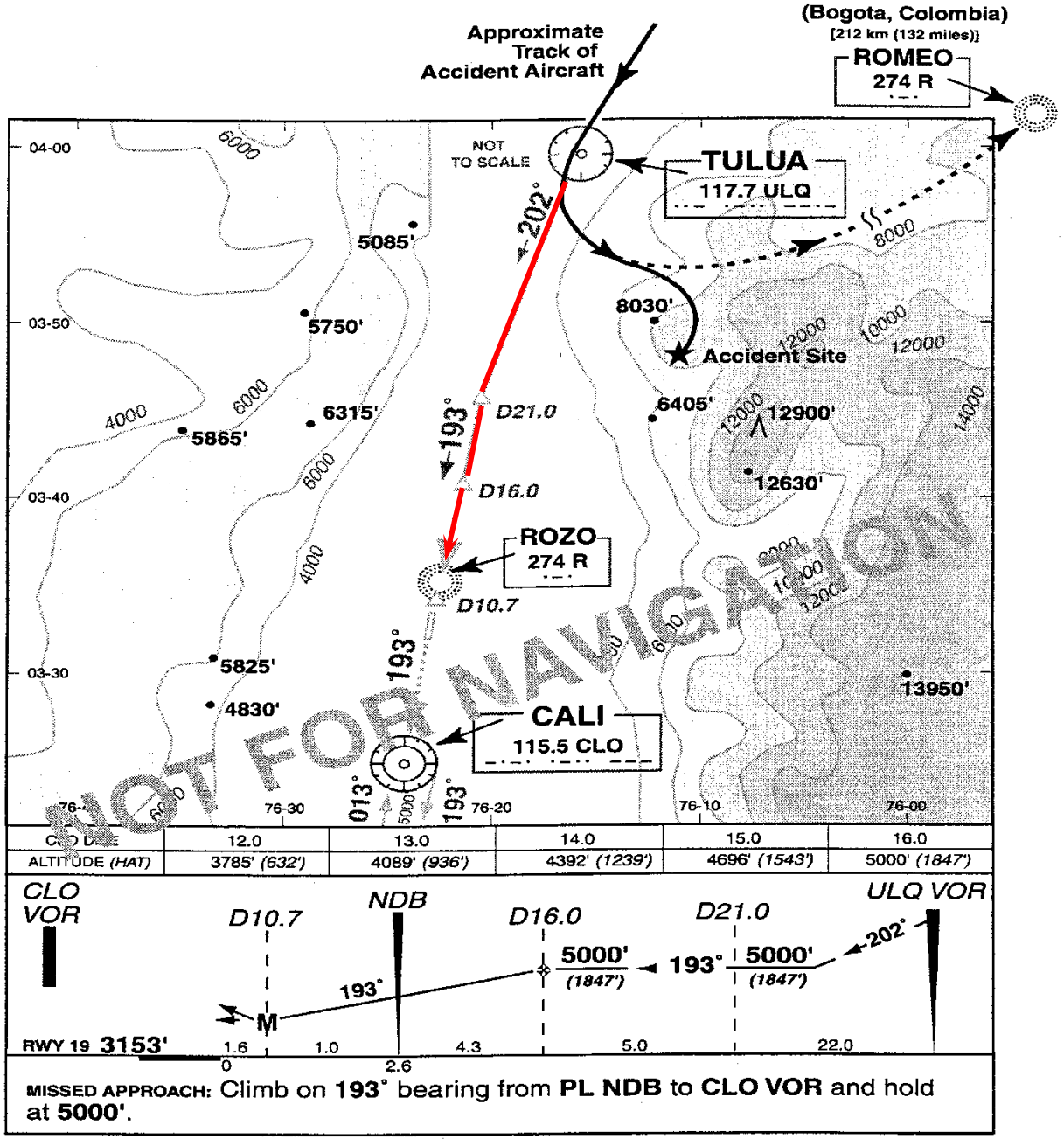
NOT TO SCALE


ACT RTE 1 LEGS 2/2
212° 45 NM
ULQ - - - / 10000
202° 22 NM
D21 CF19 - - - / 5000
193° 5 NM
D16 FF19 170 / 10000
193° 5 NM
MA19 - - - / 3920
193° 11 NM
CLO - - - / 5000
< RTE 2 LEGS RTE DATA >
TULUA
117.7 ULQ
Tulua to
Cali is
43 nm
230±
202°
22 nm
W3
MEA 8000
(low alt airway)
MSA
9200' 14,900'
D21 (CF19)
At or above 5000
193°
D16 (FF19)
ROZO
274 R
N03 35.8 W076 22.5
At or above 3900
MA19
CALI
115.5 CLO


CLO
VOR
NDB
D16.0
D21.0
ULQ
VOR
3900'
(747')
193°
5000'
(1847')
193°
5000'
(1847')
202°
M
193°
5.3 to MAP
RWY 19 3153'
APT 3162'
0
2.6
4.3
5.0
22.0

NOT TO SCALE

VOR DME Approach to Runway 19, Cali, Colombia, on Dec. 20, 1995



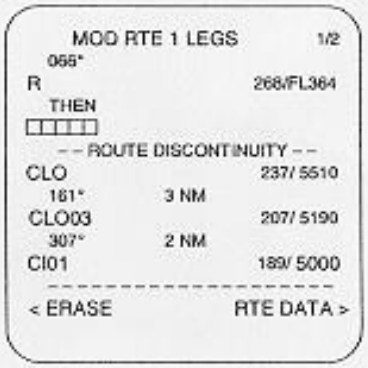
CLO DME	12.0	13.0	14.0	15.0	16.0
ALTITUDE (HAT)	3785' (632')	4089' (936')	4392' (1239')	4696' (1543')	5000' (1847')

MISSED APPROACH: Climb on **193°** bearing from **PL NDB** to **CLO VOR** and hold at **5000'**.

These CDU displays were retrieved from a circuit card from one of the Flight Management Computers. Data was retained in non-volatile memory.

FIG A

These LEGS pages make up the last MODified route prior to impact.



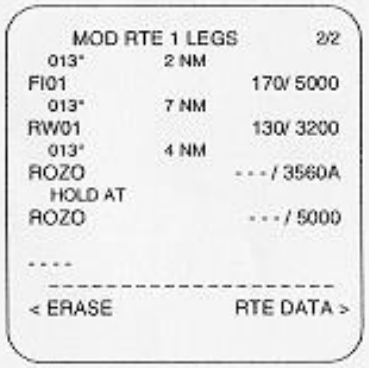
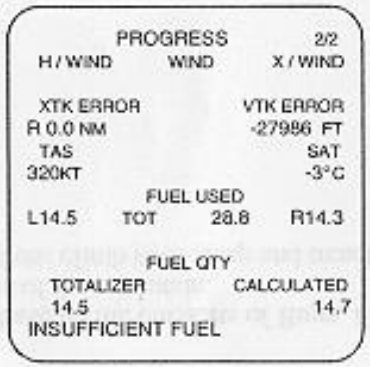


FIG B

These PROGRESS pages make up the last MODified route prior to impact.



Top of Page 14

2134:59 … Cleared to Cali VOR, descend and maintain 15,000

- AA 965 is 52 miles from AP
- 19 nm or approx. 3 min from ULQ

Middle Right Page 15

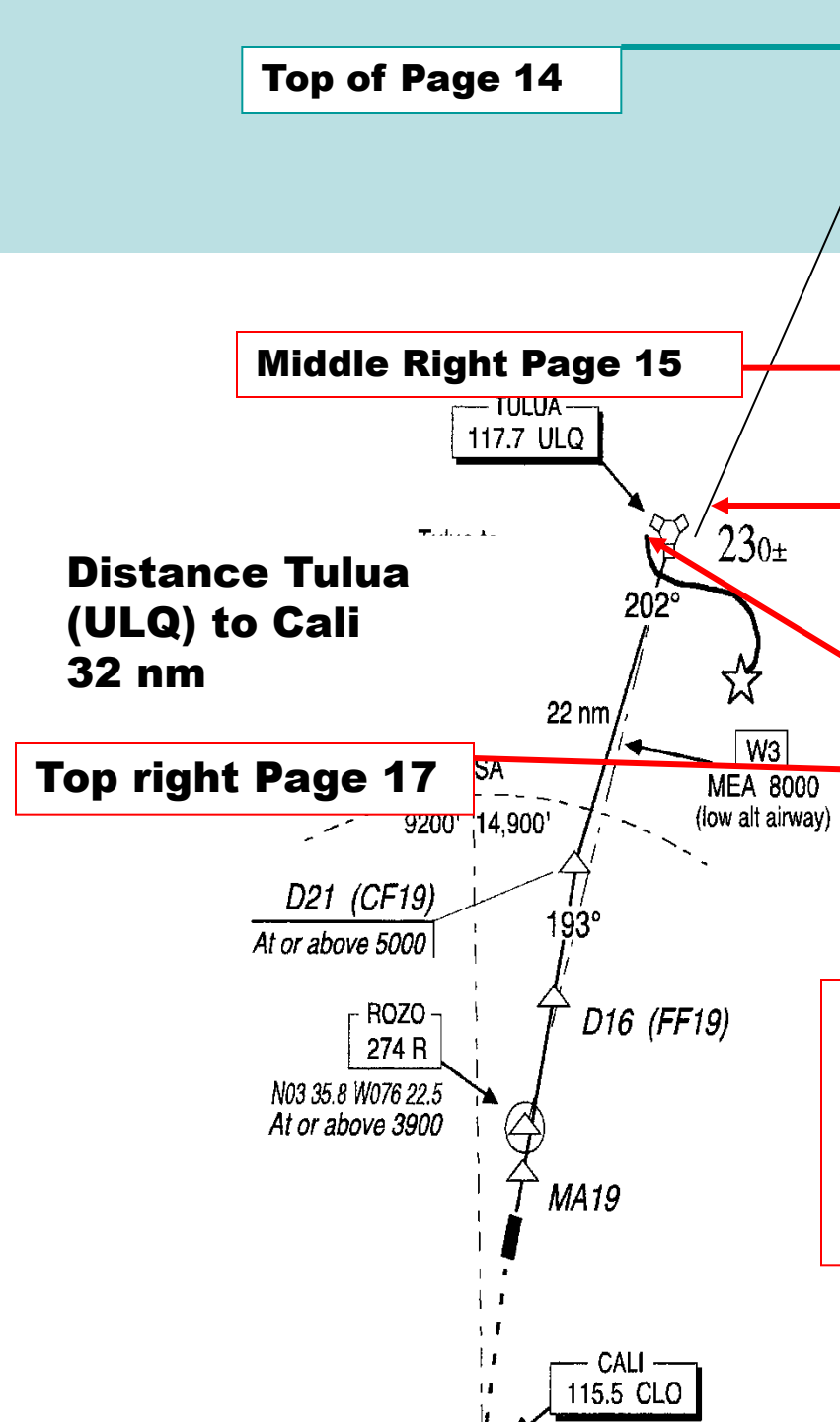
2136:31 … wind is calm are you able approach RW 19

Aircraft is:
- 1 min (5-6 NM) North of ULQ
- Descending through 19,000
- 37 -39 NM from the AP

Distance Tulua (ULQ) to Cali 32 nm

Top right Page 17

•2137:42 all right Roza one to one nine, twenty one miles, ah five thousand feet
•Capt enters "R" in FMC and executes
•Aircraft starts turn to left



Identify the THREATS and ERRORS

How did the use of automation contribute to this accident?

What automation strategies might have prevented this accident?

AA 965 - Cali

What threats did this crew encounter?

What errors contributed to this accident?

What role did automation play in this accident?

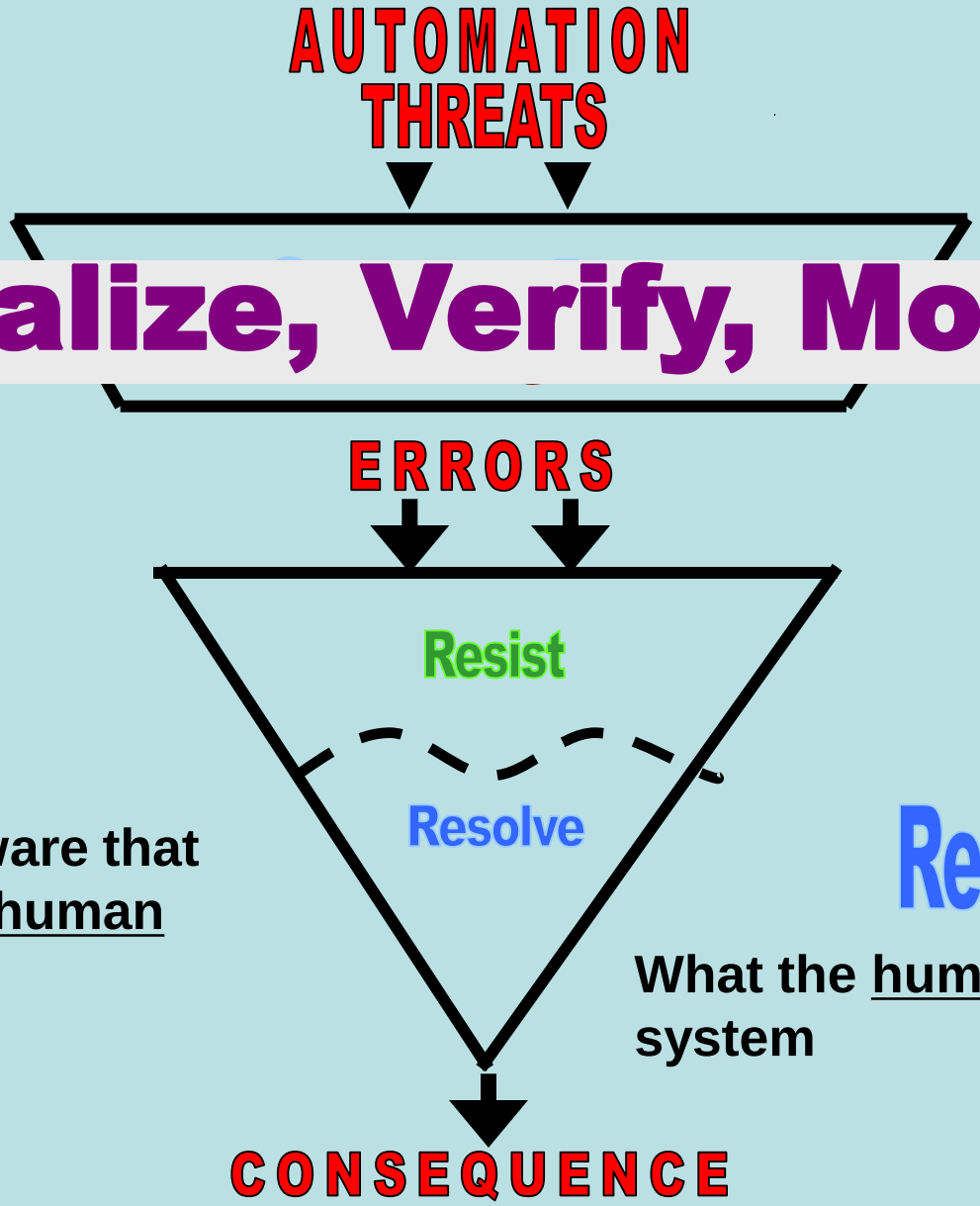
What strategies could be used to prevent a CFIT encounter with automation or without?

Cali Video

Strategies

- Fight complacency
- Clearly defined roles PF / PM
- Briefing and communication
- Management workload
- Utilize raw data
- Limit being “heads down” at critical times
- Keep basic flight skills practiced

Threat and Error Management



Resist

Hardware & Software that exists before the human enters

Resolve

What the human brings to the system

Human Centered Automation

Will:

- Reduce workload and fatigue
- Result in fewer errors
- Enhance SA
- Increase efficiency
- Enhance safety

It takes a commitment on your part